DOES MILD LEG LENGTH INEQUALITY AFFECT PLANTAR PRESSURE DISTRIBUTION DURING RUNNING?

Carla Sonsino Pereira*, **, Vitor Tessutti*, and Isabel C.N. Sacco*

*** Laboratory of Biomechanics of the Human Movement and Posture, School of Medicine, University of São Paulo, São Paulo, Brazil**
**** Centro Universitário Padre Anchieta, Jundiaí, Brazil**

The aim of this study was to investigate if a mild LLI altered plantar pressure distribution during running at approximately 12Km/h. Nowadays running can be considered one of the most important recreational activities, and mild leg length inequality (LLI), which appears to be usual among runners, has been related to running injuries. The hypothesis was that runners with mild LLI would present smaller values of plantar pressure at the lateral heel, and greater values at the medial midfoot at the long limb; and greater values at the lateral heel and lateral midfoot at the short limb in comparison with runners without LLI. Plantar pressure distribution was acquired using Pedar X mobile System. Measurements were performed under the feet of 14 runners distributed in two groups: control (LLI<0.5cm) and inequality (LLI>1.0cm). Contradicting the initial hypothesis, results demonstrated that runners with a mild LLI did not present significant differences in plantar pressure distribution in comparison to subjects without LLI, and between long and short limbs. These findings point out that analysis of plantar pressure distribution was not an efficient method for detecting small asymmetries or possible adjusts in lower limbs during running.

KEY WORDS: Biomechanics, Plantar Pressure Distribution, Running, Leg Length Inequality.

INTRODUCTION:

There is a high incidence of leg length inequality (LLI) in general population (Kaufman *et al.*, 1996), and often a mild LLI, i.e., smaller than 3.0 cm (McCaw and Bates, 1991), is considered normal unless a lower limb injury occurs. Orthopedic disorders as low back pain, osteoarthritis and stress fractures have been associated with mild LLI (McCaw and Bates, 1991; Korpelainen *et al.*, 2001), which might appear early and severely in runners due to increased mechanical loads imposed by their physical activity. Biomechanical analysis of locomotion skills provides information about compensatory mechanisms adopted by subjects with LLI in order to equalize the lower limb length such as: pelvic obliquity (Walsh *et al.*, 2000), pronation of the long limb, or supination of the short limb (D'Amico *et al.*, 1985; Bhave *et al.*, 1999), however these adaptations may cause overload in one of the limbs (Kaufman *et al.*, 1996) which might also lead to clinical symptoms and injuries.
Therefore, the purpose of this study was to investigate possible effects of mild LLI in plantar pressure distribution in runners. The hypothesis was that in runners with mild LLI plantar pressure would present smaller values at the lateral heel, and greater values at the medial midfoot at the long limb; and greater values at the lateral heel and lateral midfoot at the short limb in comparison with runners without LLI.

METHOD:

Data Collection: Fourteen experienced runners from both sexes, ranging in age from 18 to 45 years, free of injuries at the time of the data acquisition participated in this prospective study. Runners were identified by a brief interview and were invited to perform the scanogram to evaluate the presence and quantify the magnitude of the structural leg length inequality as previous described at the literature. (Terry *et al.*, 2005). After that, the runners were invited to perform a biomechanical evaluation of their running. Subjects received a full explanation regarding the aims of the study and signed a written consent statement approved by the Local Ethical Committee.
Volunteer runners were divided into two groups in accordance with the presence and magnitude of the LLI: control group (CG) - composed by 7 runners with LLI smaller than 0.5

cm (5 men; 32±4 years; 77.7±9.3 kg; mean LLI of 0.2±0.1 cm; run velocity 12.8±0.4 km/h and 2 women; 31±1 years; 64.3±12.5 kg; mean LLI of 0±0 cm; run velocity 13.2±1.5 km/h); and inequality group (IG) - composed by 7 runners with LLI greater or equal to 1.0 cm (6 men; 28±5 years; 71.1±7.1 kg; mean LLI of 1.4±0.4 cm; run velocity 12.7±1.7 km/h and 1 woman 31 years; 58.7 kg; LLI of 0.9 cm; run velocity 12.8±1.0 km/h). All subjects had practiced running at least three times a week for more than one year, and presented a heel-toe type of running.

The Pedar X mobile System (Novel GmbH, Munich, Germany) was used to acquire plantar pressure distribution. This capacitive system consisted of two flexible insoles and a portable data logger for data storage. The sampling rate was 50 Hz, and the system had a resolution of approximately one sensor per cm^2. The sensor measurement range is 30 kPa to 1.2 MPa with a sensitivity of 10 kPa. The system is reported to have a good to excellent reproducibility during running (Kernozek and Ricard, 1990; Eils *et al.*, 2004).

The insoles were fitted into subject's own running shoes, and running at approximately 12 km/h was performed (velocity of both groups were statistically matched). Subjects ran in a 10 m flat indoor walkway, and the running speed was controlled by the time to complete the walkway distance using a chronometer. Each insole was calibrated prior to the data acquisition according to the manufacturer's specifications.

Plantar pressure distribution was acquired under both feet, and in order to obtain enough measurements of each foot, running was repeated as many times as necessary (5-8 trials) until 10 valid steps were achieved for each lower limb.

Each footprint was subdivided into 6 different areas using a standardized mask that was corresponded to the sizes of the insoles (Nurse and Nigg, 2001; Eils *et al.*, 2004). The different areas were the medial (MH) and lateral heel (LH); the medial (MM) and lateral midfoot (LM); the medial (MF) and lateral forefoot (LF), including hallux and toes. The same mask for each insole was applied to all subjects' footprints.

Data Analysis: The following variables were determined for the whole foot and the selected regions: peak pressure (PP), pressure-time integrals (PTI), and maximum mean pressure (MMP).

The mean of all steps per trial, and finally the mean of all trials were calculated for each area. Statistical analyses were performed using Statistica software (StatSoft, Inc., Tulsa, USA). Data were tested for normal distribution by Shapiro Wilks test and homogeneity of variances were tested using Levenes test, and then an ANOVA (2x2x6) for each variable was performed in order to compare differences between groups and lower limbs in each plantar area. After that, if significant differences were obtained in ANOVA, Tukey test was performed to detect differences between groups. The level of significance was set at 5%.

RESULTS:

ANOVAs were conducted: for peak pressure ($F(5,60)=0,980$; $p=0,437$), for maximum mean pressure ($F(5,60)=0,139$; $p=0,982$), and for pressure–time integrals ($F(5,60)=0,873$; $p=0,504$). Confirming the ANOVAs results, Tukey test showed no statistical differences in any studied variable. Therefore, results showed that runners with LLI did not present significant differences between lower limbs, and did not present significant differences in comparison to subjects without LLI in any studied variable in all plantar areas, as demonstrated in Table 1.

Table 1 Mean and standard deviation of peak pressure (PP), maximum mean pressure (MMP), and pressure-time Integrals (PTI) in each plantar area during running for control group (CG) - and inequality group (IG)

Mask region	Variables	Short		Long	
		CG (n=7)	IG (n=7)	CG (n=7)	IG (n=7)
Medial Forefoot	PP (kPa)	360.5±112.3	334.8±69.3	307.7±102.2	351.2±111.6
	MMP (kPa)	176.6±34.2	174.8±28.7	161.1±38.0	167.8±23.7
	PTI ($kPa.s^{-1}$)	48.4± 14.3	45.7± 10.2	43.0± 16.4	47.0± 12.9
Lateral Forefoot	PP (kPa)	334.0±66.1	314.1±44.4	314.5±108.3	297.8±48.2
	MMP (kPa)	200.3±41.3	165.7±22.0	190.4±67.2	155.1±31.0
	PTI ($kPa.s^{-1}$)	48.2 ±8.4	43.5 ±6.1	46.10± 15.41	40.93± 5.07
Medial Midfoot	PP (kPa)	169.8±19.2	170.9±18.1	184.3±24.9	180.8±43.3
	MMP (kPa)	61.3±14.8	71.8±21.6	61.7±16.8	72.6±15.0
	PTI ($kPa.s^{-1}$)	20.3 ±2.5	20.2 ±4.9	21.51± 2.90	21.37± 5.28
Lateral Midfoot	PP (kPa)	228.5±41.7	179.6±16.1	227.4±36.7	183.1±36.0
	MMP (kPa)	113.3±20.7	95.9±14.0	112.6±21.6	90.9±14.4
	PTI ($kPa.s^{-1}$)	31.5 ±5.7	24.8 ±3.6	31.8±4.2	24.5±4.8
Medial Heel	PP (kPa)	297.6±95.7	244.8±56.0	329.2±62.5	273.7±73.3
	MMP (kPa)	194.7±39.6	170.8±41.3	217.0±42.5	190.3±56.3
	PTI ($kPa.s^{-1}$)	25.4 ±6.7	19.7 ±7.4	27.9±7.0	21.7±8.7
Lateral Heel	PP (kPa)	318.5±88.4	252.3±39.7	338.1±51.9	269.6±73.2
	MMP (kPa)	215.2±30.3	157.0±39.7	227.2±23.8	175.6±45.1
	PTI ($kPa.s^{-1}$)	23.9 ±5.8	19.7 ±6.6	27.1±6.6	20.9±8.6

DISCUSSION:

The purpose of this study was to investigate effects of a mild LLI in plantar pressure distribution in runners. Unexpectedly, results indicated that the presence of a mild LLI did not cause significant modifications in plantar pressure measurements during running independently of the lower limb.

During locomotion, plantar pressure distribution migrates fairly rapidly from the lateral border of the heel to the medial area of the heel forward to the forefoot (Novacheck, 1998). This distribution occurs due to the normal pattern of running that involves a foot supination at heel strike, followed by a maximum pronation, that occurs during the absorption phase while the limb is loaded, and then a supination to create a stable lever for push-off (Clarke *et al.*, 1983; Novacheck, 1998). Researchers have associated an excessive pronation of the foot during running with injury occurrence (Clarke *et al.*, 1983; Novacheck, 1998). Previous studies have also observed a more pronated foot during stance phase on the longer limb of subjects with LLI, and the authors described this result as a compensatory mechanism adopted by these subjects in an attempt of shortening their longer limb (Bloedel and Hauger, 1995; Walsh *et al.*, 2000). In the other hand, D'Amico *et al.* (1985) have found that subjects with mild LLI adopt a supination of the foot on the shorter limb in an attempt of increasing the limb length. These adaptations theories were not supported by this study, since subjects with mild LLI did not present significative differences between long and short limb, and showed no significant differences in comparison to subjects without LLI.

Therefore, plantar pressure analyses was not efficient in detecting differences between runners with and without mild LLI, indicating that it would be necessary to associate with these data a kinematic analysis to state whether these alterations are related or not to compensatory mechanisms on the feet.

CONCLUSION:

The analysis of plantar pressure distribution did not demonstrate to be an efficient method for detecting small asymmetries or possible adjusts at the lower limbs of subjects with mild LLI during running in the runners studied. Unexpectedly, runners with mild LLI did not present significant adaptations in plantar pressure distribution patterns. However, these subjects likely adopted compensatory mechanisms, which allowed them to equilibrate functionally the asymmetry resulting in an efficient pattern of locomotion.

REFERENCES:

Bhave, A., Paley, D. & Herzenberg, J. E. (1999). Improvement in gait parameters after lengthening for the treatment of limb-length discrepancy. *J Bone Joint Surg Am*, 81(4), 529-34.

Bloedel, P. K. & Hauger, B. (1995). The effects of limb length discrepancy on subtalar joint kinematics during running. *J Orthop Sports Phys Ther*, 22(2), 60-4.

Clarke, T. E., Frederick, E. C. & Hamill, C. L. (1983). The effects of shoe design parameters on rearfoot control in running. *Med Sci Sports Exerc*, 15(5), 376-81.

D'Amico, J. C., Dinowitz, H. D. & Polchaninoff, M. (1985). Limb length discrepancy. An electrodynographic analysis. *J Am Podiatr Med Assoc*, 75(12), 639-43.

Eils, E., Streyl, M., Linnenbecker, S., Thorwesten, L., Volker, K. & Rosenbaum, D. (2004). Characteristic plantar pressure distribution patterns during soccer-specific movements. *Am J Sports Med*, 32(1), 140-5.

Kaufman, K. R., Miller, L. S. & Sutherland, D. H. (1996). Gait asymmetry in patients with limb-length inequality. *J Pediatr Orthop*, 16(2), 144-50.

Kernozek, T. W. & Ricard, M. D. (1990). Foot placement angle and arch type: effect on rearfoot motion. *Arch Phys Med Rehabil*, 71(12), 988-91.

Korpelainen, R., Orava, S., Karpakka, J., Siira, P. & Hulkko, A. (2001). Risk factors for recurrent stress fractures in athletes. *Am J Sports Med*, 29(3), 304-10.

McCaw, S. T. & Bates, B. T. (1991). Biomechanical implications of mild leg length inequality. *Br J Sports Med*, 25(1), 10-3.

Novacheck, T. F. (1998). The biomechanics of running. *Gait Posture*, 7(1), 77-95.

Nurse, M. A. & Nigg, B. M. (2001). The effect of changes in foot sensation on plantar pressure and muscle activity. *Clin Biomech*, 16(9), 719-27.

Terry, M. A., Winell, J. J., Green, D. W., Schneider, R., Peterson, M., Marx, R. G., et al. (2005). Measurement variance in limb length discrepancy: clinical and radiographic assessment of interobserver and intraobserver variability. *J Pediatr Orthop*, 25(2), 197-201.

Walsh, M., Connolly, P., Jenkinson, A. & O'Brien, T. (2000). Leg length discrepancy--an experimental study of compensatory changes in three dimensions using gait analysis. *Gait Posture*, 12(2), 156-61.

Acknowledgement:
Authors would like to thank FAPESP for financial support (03/08165-7).